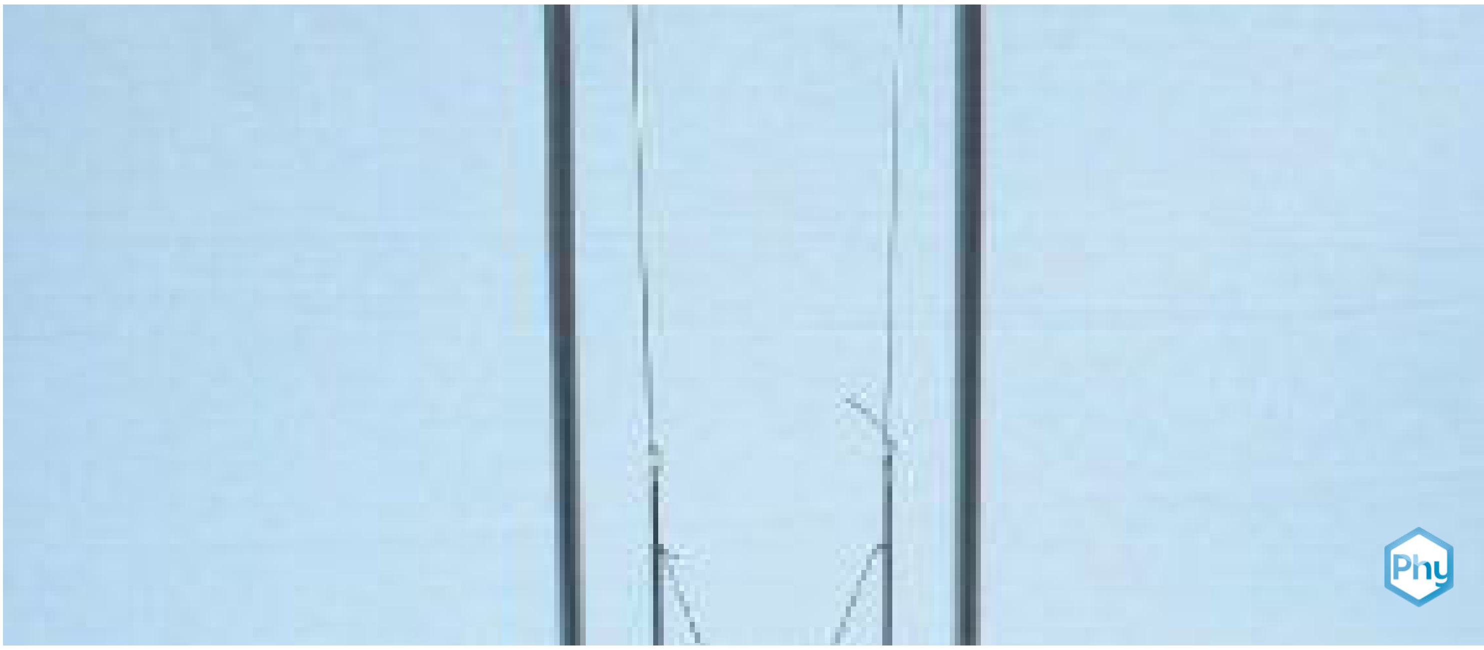
Coupled pendulum systems



Physics | Mechanics | Vibrations & waves

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/5fda7f18b5c96200036a6700

Teacher information

Application

Experimental setup for the investigation of coupled pendulums

Coupled oscillatory systems can be described exactly with the help of the Lagrangian approach. Here, one determines the potential and kinetic energy of the respective system E_{pot} and E_{kin} and forms the difference of these. For the Lagrangian function L generally the following applies:

$$L = E_{pot} - E_{kin}$$

With the help of the introduction of generalized coordinates q_i Newton's law of action ($F = \dot{p}$), using the partial derivatives, is written as:

$$\frac{d}{dt}\frac{\delta L}{\delta \dot{q}_i} - \frac{\delta L}{\delta q_i} = 0$$

However, since this approach might be a bit too complex for the students, they should only investigate the system experimentally here for the time being.

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Other teacher information (1/2)

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Prior knowledge

The students should have already learnt about forced oscillations and resonance as well as the thread pendulum. They should know that with the aid of the period of oscillation T of a system, oscillation frequency f can be determined.

Scientific principle

The period of oscillation T of the simple thread pendulum results according to:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

The frequency f is equal to the reciprocal of the period of oscillation:

$$f = 1/T = T^{-1}\,[1/s] = [Hz]$$

Other teacher information (2/2)

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Learning objective

Students will investigate and understand the behavior of a coupled oscillatory system.

Tasks

The students are to investigate the oscillation behaviour of two coupled pendulums for different initial situations (same direction and opposite direction excitation) and to determine the resulting beat frequency f_s in the case that only one pendulum is excited. In an additional task, the influence of the coupling on the beat frequency could be investigated.

To change the coupling: The masses should only be reduced, otherwise the two thread pendulums hang crooked and the measurement results become unclean. The starting point for the coupling must not be set too low, otherwise the frequency differences for equal and opposite excitation will be too small and thus the measurement errors too large.

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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Student Information

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Motivation

Aircraft landing gear

You are already familiar with oscillations and oscillatory systems. In everyday life, however, these are usually not separated in the same way as the systems you have investigated so far (thread pendulum, coil spring pendulum, etc.), but consist mostly of coupled oscillatory systems.

A classic example of this is the landing gear of an aircraft, as shown here, or that of vehicles. This consists of many individual components and oscillating components such as the tires and the installed springs and thus represent a coupled oscillation system.

In the following experiment you will deal with a coupled oscillating system.

Tasks

Observe the behaviour of two string pendulums coupled by means of a string and a mass piece.

Measure the beat duration of the coupled pendulums when only one string pendulum is excited.

Determine the period of oscillation of both pendulums when oscillating in the same direction and when oscillating in opposite directions.

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Equipment

Position	Material	Item No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, l = 600 mm, d = 10 mm, split in 2 rods with screw threads	02035-00	2
3	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
4	Support rod with hole, stainless steel, 10 cm	02036-01	2
5	Boss head	02043-00	2
6	Weight holder, 10 g	02204-00	2
7	Slotted weight, black, 10 g	02205-01	2
8	Slotted weight, black, 50 g	02206-01	2
9	Set of precision weights,1g-50g	44017-01	1
10	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1
11	Measuring tape, l = 2 m	09936-00	1
12	Fishing line, l. 20m	02089-00	1

Additional equipment

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Position	Equipment	Quantity
1	Scissors	1

Set-up (1/2)

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Connect the two halves of the support base to the support rod 25 cm and tighten the locking levers.

Screw the two split support rods together to form two long rods. Place these two support rods (60 cm) in the support base halves and screw them tight.

Connecting the support base halves

Screwing the support rod

Attaching the support rod

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Set-up (2/2)

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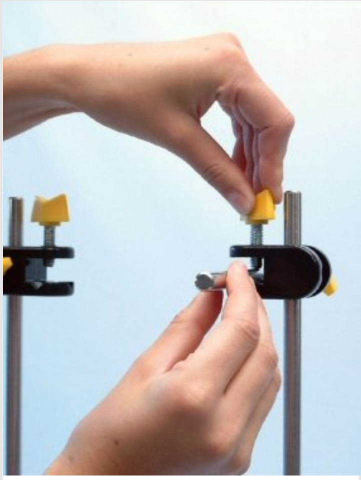

Mount support rods in boss head

Clamp the two short support rods with the boss heads to the upper end of the long support rods.

Use it to build two exactly equal thread pendulums with $40\ cm$ pendulum length and a mass of $m = 70\ g$. The distance between the two suspension points should be $10\ cm$ must be the same. The pendulums should have the same period of oscillation! (Possibly adjust a pendulum length a little).

Attach in the middle of a piece of fishing line ($20\ cm$ long) a mass piece $10\ g$. Attach both ends to the top of each weight plate.

Build up of two equal thread pendulums

Procedure (1/2)

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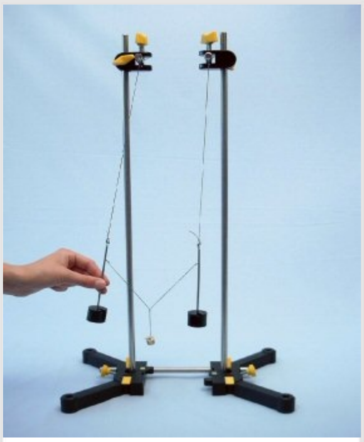

Deflection of the thread pendulum

- Get the system swinging by swinging a pendulum about $4\ cm$ to the side.
- Let go of the pendulum and first observe the behavior of both pendulums.
- Measure the beat time of the two coupled string pendulums: Determine the time T between two stops of a pendulum. Repeat the measurements twice and record the measured times in Table 1 in the report.

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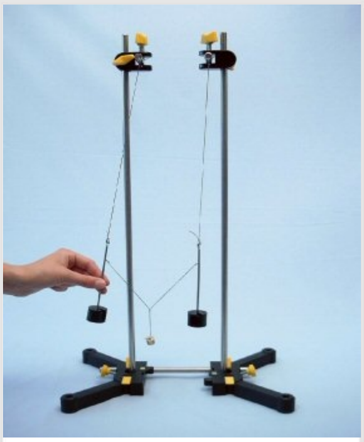
Procedure (2/2)



Deflection of the thread pendulum

- Then determine the period of oscillation of a pendulum, if
  - both pendulums are deflected to same side (same sense) and same distance.
  - both pendulums are deflected to different sides (opposite sense) and same distance.
- Measure the time for 10 oscillations and repeat these measurements twice.
- Enter the first measured values for the same direction measurement in Table 2 in the report.
- Enter the second measured values for the opposite measurement in Table 3 in the report.

Report

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Table 1

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Enter your measurements for the beat duration T_s and calculate from the values the mean value for the beat duration $\langle T_s \rangle$ of the pendulum and the beat frequency f_s.

Calculate the frequency from the period of oscillation:

$$f_s = \frac{1}{T_s} = T_s^{-1}\ [Hz \triangleq \frac{1}{s}]$$

Measurement	$T_s\ [s]$
1	
2	
3	

$\langle T_s \rangle\ [s]$	$f_s\ [Hz]$

Table 2

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Enter your measured values for the oscillation period of 10 periods with excitation in the same direction and the corresponding oscillation periods T for one oscillation. Then calculate the mean value T_1 and the frequency f_1 for the same directed excitment.

$$f_1 = \frac{1}{T_1}$$

Measurement no	$t_{10}\ [s]$	$T\ [s]$
1		
2		
3		

$T_1\ [s]$	$f_1\ [Hz]$

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Table 3

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Enter your measured values for the oscillation period of 10 periods with opposite excitation and the corresponding oscillation periods. T for one oscillation. Then calculate the mean value T_2 and the frequency f_2 for the opposite excitment.

$$f_2 = \frac{1}{T_2}$$

Measurement no	$t_{10}\ [s]$	$T\ [s]$
1		
2		
3		

$T_2\ [s]$	$f_2\ [Hz]$

Task 1

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Drag the words to your observation to the correct places.

Due to the ________ of the pendulums, ________ is transferred from the first pendulum to the second, which in turn begins to ________. The loss of energy at the first pendulum leads to a ________ of its amplitude until it ________. The second pendulum has now reached its greatest ________. Then the energy transport starts again, but now backwards from the ________ pendulum to the ________. Thus the ________ is reached again, the process begins anew.

- first
- swing
- second
- amplitude
- coupling
- energy
- stops
- starting state
- decrease

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Task 2

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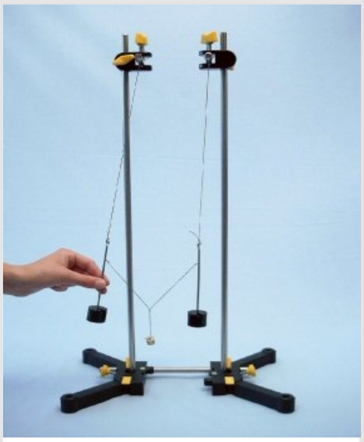


Deflection of the thread pendulum

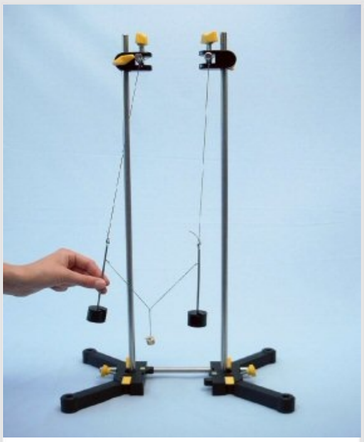
A swinging pendulum has oscillation energy in the form of potential and kinetic energy. Can you explain the processes observed in the coupled pendulums using an energy approach?

- The system always has only potential energy.
- There is constant change of potential and kinetic energy of each mass (left and right side).
- The system always has only kinetic energy.

Check

Task 3

PHYWE



Deflection of the thread pendulum

Calculate the difference of the oscillation frequencies for equal and opposite excitation $f_2 - f_1$. Compare the result with the beat frequency determined by you f_s What do you find?

- $f_s > f_2 - f_1$
- $f_s = f_2 - f_1$
- $f_s < f_2 - f_1$

Check

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Slide	Score / Total
Slide 19: Observation coupled pendulums	0/9
Slide 20: conversion of E_{pot} and E_{kin}	0/1
Slide 21: Comparison of \Delta f and f_s	0/1

Total 0 / 11

Solutions Repeat Export text

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